

# **Evaluation of Tuberculin Testing in Cervidae**

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# Preface

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This evaluation was initiated in response to a request by the United States Animal Health Association's Scientific Advisory Subcommittee of the Tuberculosis Committee. This document is not intended to be quoted or cited in scientific literature. Inclusion of original data or information in this report is not intended to preclude its copyrighted publication in peer-reviewed scientific journals.

## Contributors

USDA: Animal and Plant Health Inspection Service (APHIS),  
Veterinary Services (VS)

*Dianne Norden* - Centers for Epidemiology and Animal Health  
(CEAH)

*Mitchell A. Essey* - National Animal Health Program Staff

*Robert Meyer* - VS Western Region

## Acknowledgments

USDA:APHIS:VS:CEAH

*Randy Pritchard*

*Rodney Howe*

*Michael Dalrymple*

*Brian Trout*

Texas A&M Department of Veterinary Pathobiology

*Donald S. Davis*

## Executive Summary

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This study evaluates the sensitivity and specificity of tuberculin skin tests used in Cervidae. Blood tuberculin (BTB) test data was also analyzed descriptively. Two databases were created by entering data on skin tests performed nationwide between January 1, 1991 and March 31, 1996 as part of the Bovine Tuberculosis Eradication Program. The first database consisted of 3,624 herd summary tests for the single cervical test (SCT). The second database was comprised of data from over 2,200 individual comparative cervical tests (CCTs) performed on 1,750 cervids as well as their necropsy, histology and culture results. A third database provided by the BTB Diagnostic Lab at Texas A&M University, assembled BTB test results since May 1994.

SCT response rates for animals from herds having no evidence of tuberculosis infection were calculated annually for each state and Veterinary Services (VS) region. The largest national response rate of 3.3 percent was reported in 1995. Overall, tests performed in the Northern region were 2.7 times less likely to be classified as positive to the SCT than for all other regions combined ( $p < .001$ ). The difference in the SCT response rates between deer (2.8 percent) and elk (1.8 percent) was significant at  $p < 0.05$ . Limitations in the data prevented the calculation of individual animal sensitivity for the SCT and the CCT. Using *M. bovis* isolation from any animal in the herd as a gold standard resulted in a herd sensitivity for the SCT of 100 percent (14/14). Individual animal specificity for the CCT conducted in series with SCT was 88.4 percent (1017/1151). Animals from apparently negative herds from VS' Northern region were three times less likely to have a false positive result to the CCT than animals from all other regions combined. CCT herd sensitivity and specificity were 90.5 percent (19/21) and 93.4 percent (219/229) respectively.

The BTB Diagnostic Laboratory performed 689 tests of 579 cervids between May 1994 and June 1996. Test results for the 689 tests were as follows: avian, 37.2 percent, negative, 34.7 percent, equivocal, 12.9 percent, no data, 11.5 percent, and bovine, 3.8 percent. Elk and red deer were 3 times as likely to have a negative result as all other species of cervids tested. Deer were over 4 times as likely to have an avian test result than elk and red deer.

Reasons for differences in response rates to the SCT and CCT in negative herds could be due to a variety of factors including differences in the immune response of the animals, differences in application and interpretation of the test, and differences in exposure to mycobacteria other than *M. bovis*. Assumptions for the disease status of herds and individual animals were necessary, and may or may not reflect the true situation. In order to collect the necessary data for individual animal sensitivity calculations, it is recommended that the guidelines outlined in "Criteria for evaluating experimental tuberculosis test performance for official test status" be followed. If individual animal sensitivity values were made available, a dynamic model could be developed that could predict the epidemiologic and economic impact of occult disease.

# Introduction

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Responding to a request from the United States Animal Health Association (USAHA), an evaluation was made of the sensitivity and specificity of the tuberculin skin tests used in Cervidae. Tuberculin tests included the single cervical test (SCT) and the comparative cervical test (CCT). The blood tuberculin test (BTB) data was analyzed descriptively.

Other countries have evaluated the sensitivity and specificity of tuberculin skin tests using testing protocols similar to those used in the United States. In naturally infected red deer, the sensitivity of the SCT has been reported to be between 82.4 percent (84/102) and 85 percent (Griffin et al. 1994, cited in Carter et al. 1984). Researchers de Lisle, Corrin and Carter (1984) demonstrated the sensitivity in experimentally infected red deer to be 86 percent (36/44). Specificity of the SCT varied more widely, ranging from 45.9 percent (100/218) in red deer from negative herds (Griffin et al. 1994) to 76.4 percent (347/454) also in red deer (Carter et al. 1984). In Tasmania, which is free from bovine tuberculosis, researchers found that defining a positive animal as one in which the bovine response was 1mm or greater gave a specificity of 73.5 (25/34) percent, but setting the reactor response at 2 mm or greater yielded a specificity of 100 percent in farmed fallow deer (Lloyd-Webb et al. 1995). In a report presented to the USAHA's TB Committee in 1994, analysis of test data on cervids in herds from Veterinary Service's Western region not known to be infected suggested that specificity may be as high as 97 percent (R. Meyer, personal communication).

Evaluation of the sensitivity of the CCT in naturally infected cervids has been limited to small herds. Sensitivity was reported to be 80 percent (16/20) in red deer not previously SCT tested (Stuart et al. 1988). The CCT sensitivity in experimentally infected New Zealand

deer single cervical tested at least 120 days previously was 92 percent (Carter, et al. 1986). Carter and others (1986) defined negative animals as those originating from a herd that regularly tested negative and from which *M. bovis* was never isolated. The specificity of the CCT was determined to be 98.5 percent (1583/1606) (Carter, et al. 1986).

A New Zealand study examined the sensitivity of the BTB test in naturally infected red deer. The researchers found the sensitivity of the BTB to be 95.7 percent (139/145) (Griffin et al. 1994). Specificity of the BTB test was calculated to be 98 percent (196/200). Animals with test results that were not definitively positive or negative (i.e., equivocal or “no data” results) were not included in either the sensitivity or specificity calculations for the BTB test (Griffin et al. 1994). Eighteen or 8.3 percent of the “disease negative” animals originating from negative herds had equivocal or “no data”, but only 5 or 3.3 percent of the animals that were culture positive were designated as equivocal or “no data” (Griffin et al. 1994). The sensitivity of the BTB test with no prior skin test was shown to be 90.8 percent (79/87) (Griffin et al. 1994). Sensitivity increased to 95.9 percent (94/98) when the BTB test was performed from blood obtained 10 days after the SCT (Griffin et al. 1994). However, an unpublished study by Agriculture Canada (1993) in infected elk found that the sensitivity of the BTB test may be lower than previously reported.

# Methods

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## Definitions

**Elk** - For individual animals, includes both red deer and wapiti, unless red deer are specifically mentioned. When species was reported as “deer”, or “cervid”, the test was included in the deer stratum.

**Infected status for individual animals** - *M. bovis* isolate.

**Non-infected status for individual animals** - animals from a negative herd.

**Exposed status for individual animals** - any animal which has been a member of, or in contact with an infected herd.

**Positive or infected herds** - herds in which *M. bovis* has been isolated from at least one animal in the herd at any time during the study.

**Exposed herds** - herds in which any member has been in or in contact with an infected herd, but from which *M. bovis* has not been isolated. An exposed herd was considered negative if exposed animals were depopulated and their disease status was determined to be negative. If the exposed animals remain in the herd, the herd was considered exposed regardless of the skin test results.

**Negative herds** - herds from which *M. bovis* has never been isolated, and no members of the herd originate from a herd from which *M. bovis* has been isolated.

## Data Collection and Analysis

Cervid tuberculin test results for tests performed between January 1, 1991 and March 31, 1996 were requested from individual state and federal offices. These field tests were performed as part of the eradication program for tuberculosis, rather than for the primary purpose of evaluating tuberculin tests. Data were entered into two

Epi Info<sup>1</sup> databases. The first database assembled herd summary data for the SCT. The second database (hereafter referred to as the CCT database) contained individual animal data on the SCT and CCT data provided by these state and federal offices. Tests from livestock markets or dealers were not included in the analysis because the history of the animals tested was not known.

Histology and culture results for all cervids necropsied for tuberculosis for the same time period were requested from the National Veterinary Services Laboratory (NVSL). NVSL data was merged with the CCT database. A third database for BTB test data was provided by the BTB Diagnostic Laboratory at Texas A&M University. This database contained BTB test data performed on cervids since May 1994.

Descriptive statistics were generated from each of the three databases. When sufficient data were available, analyses were stratified on species (deer and elk) and on regions of the United States. Some herds in the SCT database contained both deer and elk. These herds were included in the overall herd analyses, but only those herds that contained only deer or only elk were considered for the stratified analyses. The BTB test and the CCT could not be compared due to the limited number of animals that had undergone both tests.

### **Single Cervical Test**

The SCT database included some herds which were tested more than once during the study period. In order to decrease the likelihood of double counting animals that may have been tested more than once, response rates for animals from negative herds were calculated for each year. By calculating rates annually, an animal would have to be tested more than once a year to be counted more than once. Estimates of SCT herd specificity were also calculated on an annual basis for the same reason. A herd test had to include at

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<sup>1</sup>Epi Info 6: A word processing, database and statistics program for public Health. Version 6.02, October 1994.

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least 10 animals from a defined negative herd to be used in SCT herd specificity analysis.

Individual animal sensitivity for the SCT could not be evaluated because SCT negative animals were not sacrificed to determine their true disease status.

For SCT herd sensitivity, a positive test was defined as any animal in the herd classified as a responder to the SCT. Two gold standards were used as denominators or disease positive data. The first gold standard included only infected herds. The second gold standard included infected and exposed herds. Only herd tests with more than 10 animals were used in the evaluation.

### **Comparative Cervical Test**

For all analyses, if an animal was tested more than once, only the first recorded test was included. Only animals from negative herds were considered disease negative for the individual CCT specificity analysis. Test negative animals were those designated as negative to the CCT according to the Uniform Methods & Rules (UM&R).

There were not enough CCT negative animals sacrificed from infected herds to determine the true disease status in order to calculate individual CCT sensitivity. The CCT results of the false negative animals whose disease status was determined are reported.

The two gold standards and definitions for positive herd tests used in the computation of the SCT herd sensitivity were identical to those used in the respective CCT herd calculation. A positive herd test was defined as one or more animals in the herd classified as a suspect or a reactor to the CCT. Only negative herds were considered for CCT herd specificity computations. Because the SCT and CCT are applied sequentially in the U.S. bovine tuberculosis eradication program, herd sensitivity of the CCT alone is identical to herd sensitivity of the two tests in combination.

# Results

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## Single Cervical Test

Summary data from 3,624 herd tests from 42 states were entered into the SCT database. Over 66,000 individual tests were performed: 40,421 on deer, 25,576 on elk and 924 tests on animals from herds with both deer and elk. New York, Texas and Colorado reported the most number of tests: 14,320, 13,652 and 12,084 respectively. The most common reason given for testing was for sale-show (71.7 percent) followed by herd accreditation (11.1 percent). From test charts in which the number of animals in the herd was given, herd size ranged from 1 to 2,300, with a median of 24 animals. Eighteen infected herds were represented in this database.

The annual number of SCTs and SCT responders in herds not known to be infected or exposed for each state, grouped by VS' region of the United States, (Western, Central, Southeastern and Northern) are shown in Tables 1-4. Table 5 summarizes the response rates for each region for 1991 through 1996. Annual response rates for the four regions of the country ranged from 0.2 percent in the Northern region in 1991 to 5.1 percent in the Southeast region in 1994. The largest national response rate of 3.3 percent was reported in 1995. The national response rate is the same for the first quarter of 1996. Overall, SCTs performed in the Northern region were 2.7 (95 percent CI 2.3, 3.2) times less likely to be classified as positive than in all other regions combined ( $p < 0.001$ ). Table 6 shows the total SCTs by region for all cervids and for animals from herds not known to be infected or exposed consisting entirely of deer or entirely of elk. Totals for all cervids exceed that of the sum of totals for deer and elk because it was not possible to determine the species of animals from mixed herds tested. Some animals may be represented in these totals more than once because they may have been tested more than once. The difference in the response rates between deer (2.8 percent) and elk (1.8 percent) was significant at  $p < 0.05$ .

Annual estimates of SCT herd specificity for all cervids and for the strata of deer and elk are shown in Table 7. The estimated herd specificity for all cervids ranged from 71 to 86 percent. Specificity for all cervids and for deer and elk has decreased each year. Some cervid herds contained both deer and elk, thus the total number of cervid herds may exceed the sum of deer herds and elk herds.

The true disease status of SCT negative animals could not be determined because the animals were not necropsied. Thus false negative animals could not be identified for individual SCT sensitivity calculations. Under the first gold standard, 14 herds were identified. At least one animal responded to the SCT in each of the 14 herds, for a herd sensitivity of 100 percent. The second gold standard added known exposed herds. Herd sensitivity for Gold Standard 2 was 95.5 percent (21/22).

### **Comparative Cervical Test**

Between 1991 and the first quarter in 1996, a total of 42 states performed more than 2,200 CCTs on cervids involving 1,750 animals (1041 deer, 709 elk). The databases included information on animals from 21 known infected herds and 7 known exposed herds. Figure 1 shows the number of animals receiving the comparative cervical test each year by region of the United States. More than 450 animals were comparative cervical tested more than once. If an animal was tested more than once, only the first recorded test was included.

Individual animal CCT specificity for all cervids was calculated to be 88.4 percent (1017/1151). Specificity was 87.1 percent (614/705) and 90.4 percent (403/446) for deer and elk respectively. No significant difference between the specificity of deer and elk was identified. Table 8 shows the specificity for all cervids and for deer and elk for each region. Animals from negative herds in the Northern region were 3.3 (95 percent CI 1.8,6.3) times less likely to have a false positive result to the CCT than animals from all the other three regions combined ( $p < 0.001$ ). CCT herd specificity was 93.4 percent (219/229) for all cervids.

There were 14 CCT test negative animals from which *M. bovis* was subsequently isolated. These animals were from seven infected herds. Of these, nine had no bovine response. At least three of the nine converted to positive status after subsequent CCTs. Table 11 shows the bovine and avian response of these animals.

Herd sensitivity for Gold Standard 1 was 90.5 percent (19/21) and 78.6 percent for Gold Standard 2 (22/28). Table 9 shows herd CCT sensitivity for the two gold standards for all cervids and the deer and elk strata. Because some herds contained both deer and elk, the sum of the deer and elk herds will be greater than the total of all cervid herds.

Figures 2-5 show scatterplots of the size of reaction to bovine PPD vs. avian PPD for true positive animals, false positive animals, true negative animals and false negative animals. False negative animals were assumed to be infected at the time of testing. Frequency distributions are shown in Tables 10, 11 and 12. The gold standard for a positive animal was an *M. bovis* isolation. Disease negative animals were from herds not known to be infected or exposed.

### **BTB Test**

The BTB Diagnostic Laboratory at Texas A&M University provided data on all cervids tested since May 1994. The lab performed 689 tests on 579 animals between May 1994 and June 1996 (Figure 7). There were 26 tests and 22 animals from infected herds. The Central region accounted for 71.4 percent of the testing with almost 99 percent of those tests performed on cervids from Texas (Figure 6). BTB tests were performed on 37 premises (Figure 8). Two of these premises were infected. About 40 percent of the premises were located in the Northern region, but these premises accounted for only about 13 percent of the animals tested. Fallow deer were tested most frequently (31.8 percent) followed by red deer (26.4 percent), reindeer (18.1 percent) and elk (15.1 percent). Of the 37 premises, 13 raised elk, 10 fallow, 6 red deer, 3 reindeer, 3 white-tailed deer, and 2 raised both fallow deer and sika deer (Figure 9).

BTB test results for all species were split between “avian” (37.2 percent) and “negative” (34.7 percent). “Bovine” results were reported for 3.8 percent of the tests. Of these 26 bovine results, 11 were cervids from infected herds. Nearly a quarter of the tests had “equivocal” or “no data” results requiring the animal to be retested (Figure 10). When results were examined by species (deer vs. elk), deer were over four times (95 percent CI 2.89, 6.04) as likely to have an avian test result than elk and red deer ( $p < .01$ ). Elk and red deer were over three times (95 percent CI 2.41, 4.75) as likely to have a negative result compared to all other species of cervids tested ( $p < .01$ ). See Figure 10 for the percentage of results for all animals tested, for deer, and for elk and red deer.

**Table 1. The annual number of SCTs and SCT responders in herds not known to be infected or exposed for each state in the Western Region.**

|              | <b>1991</b>      | <b>1992</b>      | <b>1993</b>      | <b>1994</b>      | <b>1995</b>      | <b>1996*</b>     |
|--------------|------------------|------------------|------------------|------------------|------------------|------------------|
| <b>WA</b>    | 71 (0)           | 19 (0)           | 64(6)            | 391 (1)          | 339 (6)          | 247 (3)          |
| <b>OR</b>    | 86 (0)           | 11(0)            | -                | -                | -                | -                |
| <b>CA</b>    | -                | -                | 11(4)            | 45 (13)          | 102 (14)         | -                |
| <b>ID</b>    | 186 (3)          | 172 (5)          | -                | 58 (6)           | 92 (4)           | -                |
| <b>UT</b>    | 7 (0)            | 2 (0)            | -                | -                | -                | -                |
| <b>AZ</b>    | 79 (27)          | -                | -                | -                | -                | -                |
| <b>MT</b>    | 169 (3)          | 252 (0)          | 82 (1)           | 87 (9)           | 150 (0)          | 1(0)             |
| <b>WY</b>    | 10 (0)           | 29 (0)           | -                | -                | -                | -                |
| <b>CO</b>    | 619 (15)         | 1421(21)         | 3558 (54)        | 2044 (39)        | 2831 (44)        | 845 (50)         |
| <b>NM</b>    | 10(4)            | -                | -                | -                | -                | -                |
| <b>NV</b>    | -                | -                | 1(0)             | -                | -                | -                |
| <b>Total</b> | <b>1,237(52)</b> | <b>1,906(26)</b> | <b>3,716(66)</b> | <b>2,625(68)</b> | <b>3,514(68)</b> | <b>1,093(53)</b> |

\* 1996 data from Jan. 1 - March 31 only.

- indicates that no data were available.

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**Table 2. The annual number of SCTs and SCT responders in herds not known to be infected or exposed for each state in the Central Region.**

|              | <b>1991</b> | <b>1992</b> | <b>1993</b> | <b>1994</b> | <b>1995</b> | <b>1996*</b> |
|--------------|-------------|-------------|-------------|-------------|-------------|--------------|
| <b>ND</b>    | 87 (4)      | 145 (1)     | 684 (1)     | 330 (0)     | 715 (2)     | 344 (3)      |
| <b>SD</b>    | 166 (0)     | 23 (0)      | 190 (0)     | 66 (1)      | -           | -            |
| <b>NE</b>    | 147 (4)     | 39 (0)      | -           | -           | -           | -            |
| <b>KS</b>    | 66 (0)      | 114 (9)     | 178 (2)     | 39 (0)      | 106 (0)     | 73 (0)       |
| <b>OK</b>    | 6 (1)       | 30 (6)      | 74 (20)     | 136 (29)    | -           | -            |
| <b>TX</b>    | 1956 (76)   | 2611(105)   | 3024(116)   | 932 (42)    | 3855(258)   | 723 (56)     |
| <b>IA</b>    | 66 (0)      | 235 (0)     | 298 (0)     | 484 (8)     | 864 (10)    | 430 (0)      |
| <b>MO</b>    | 266 (1)     | 474 (0)     | 628 (0)     | 648 (1)     | 678 (1)     | 23 (0)       |
| <b>AR</b>    | 4 (0)       | 11 (0)      | 13 (1)      | 3 (0)       | 123 (4)     | -            |
| <b>LA</b>    | 1 (0)       | 9 (0)       | -           | 1 (1)       | -           | -            |
| <b>Total</b> | 2,765 (86)  | 3,691 (121) | 5,089 (140) | 2,639 (82)  | 6,341 (275) | 1,593 (59)   |

\* 1996 data from Jan. 1 - March 31 only.

- indicates that no data were available.

**Table 3. The annual number of SCTs and SCT responders in herds not known to be infected or exposed for each state in the Southeastern Region.**

|              | <b>1991</b>    | <b>1992</b>     | <b>1993</b>     | <b>1994</b>     | <b>1995</b>     | <b>1996*</b> |
|--------------|----------------|-----------------|-----------------|-----------------|-----------------|--------------|
| <b>KY</b>    | 12 (0)         | 11 (0)          | 14 (0)          | 73 (4)          | 88 (0)          | -            |
| <b>TN</b>    | 70 (0)         | 90 (0)          | 474 (11)        | 418 (8)         | 371 (3)         | -            |
| <b>NC</b>    | 16 (0)         | 23 (0)          | 47 (0)          | -               | -               | -            |
| <b>GA</b>    | 40 (4)         | 101 (8)         | 69 (12)         | 40 (3)          | 55 (4)          | -            |
| <b>AL</b>    | -              | 16 (0)          | 1 (0)           | 31 (0)          | 19 (0)          | -            |
| <b>MS</b>    | 35 (4)         | 185 (5)         | 40 (6)          | 262 (27)        | 242 (18)        | 1 (0)        |
| <b>FL</b>    | 71 (0)         | 91 (0)          | 9 (0)           | -               | -               | -            |
| <b>Total</b> | <b>244 (8)</b> | <b>517 (13)</b> | <b>654 (29)</b> | <b>824 (42)</b> | <b>775 (25)</b> | <b>1 (0)</b> |

\* 1996 data from Jan. 1 - March 31 only.

- indicates that no data were available.

**Table 4. The annual number of SCTs and SCT responders in herds not known to be infected or exposed for each state in the Northern Region.**

|              | <b>1991</b>      | <b>1992</b>       | <b>1993</b>       | <b>1994</b>       | <b>1995</b>        | <b>1996*</b>   |
|--------------|------------------|-------------------|-------------------|-------------------|--------------------|----------------|
| <b>MN</b>    | 106 (0)          | 95 (0)            | -                 | 85 (1)            | 93 (9)             | 96 (2)         |
| <b>WI</b>    | 272 (3)          | 1152(32)          | 521(5)            | 617 (9)           | 902 (26)           | 490 (1)        |
| <b>IL</b>    | 118 (0)          | 531 (0)           | 391(6)            | 202 (0)           | 235 (0)            | 70 (0)         |
| <b>IN</b>    | 23 (0)           | 59 (0)            | -                 | 23 (0)            | 10 (0)             | -              |
| <b>MI</b>    | 286 (0)          | 227 (3)           | 8(0)              | -                 | 2 (0)              | -              |
| <b>OH</b>    | 106 (0)          | 58(0)             | -                 | -                 | 4 (0)              | -              |
| <b>WV</b>    | -                | 1(0)              | 1(0)              | -                 | -                  | -              |
| <b>VA</b>    | 63 (2)           | 71(6)             | 107 (3)           | 722 (45)          | 946 (86)           | 96 (0)         |
| <b>NY</b>    | 1155 (0)         | 3361 (0)          | 3764 (0)          | 1908 (0)          | 1976 (1)           | 208 (4)        |
| <b>VT</b>    | -                | 2 (0)             | -                 | -                 | -                  | -              |
| <b>MA</b>    | 8 (0)            | -                 | -                 | -                 | -                  | -              |
| <b>ME</b>    | 1 (0)            | 6 (0)             | -                 | -                 | -                  | -              |
| <b>NJ</b>    | -                | 60 (1)            | 41(0)             | 156 (0)           | 32 (0)             | -              |
| <b>Total</b> | <b>2,138 (5)</b> | <b>5,623 (42)</b> | <b>4,833 (14)</b> | <b>3,713 (55)</b> | <b>4,200 (122)</b> | <b>960 (7)</b> |

\* 1996 data from Jan. 1 - March 31 only.

- indicates that no data were available.

**Table 5. Summary of the annual number of SCT tests and SCT responders in herds not known to be infected or exposed for each region.**

|                  | <b>1991</b>         | <b>1992</b>          | <b>1993</b>          | <b>1994</b>         | <b>1995</b>          | <b>1996*</b>        | <b>Total</b>                  |
|------------------|---------------------|----------------------|----------------------|---------------------|----------------------|---------------------|-------------------------------|
| <b>Western</b>   | 1237 (52)<br>4.2%   | 1906 (26)<br>1.4%    | 3716 (65)<br>1.8%    | 2625 (68)<br>2.6%   | 3514 (68)<br>1.9%    | 1093 (53)<br>4.8%   | <b>14,091<br/>(333) 2.4%</b>  |
| <b>Central</b>   | 2765 (86)<br>3.1%   | 3691 (121)<br>3.3%   | 5089 (140)<br>2.8%   | 2639 (82)<br>3.1%   | 6341 (275)<br>4.3%   | 1593 (59)<br>3.7%   | <b>22,118<br/>(763) 3.4%</b>  |
| <b>Southeast</b> | 244 (8)<br>3.3%     | 517 (13)<br>2.5%     | 654 (29)<br>4.4%     | 824 (42)<br>5.1%    | 775 (25)<br>3.2%     | 1 (0)<br>0%         | <b>3,015 (117)<br/>3.9%</b>   |
| <b>Northern</b>  | 2138 (5)<br>0.2%    | 5623 (42)<br>0.7%    | 4833 (14)<br>0.3%    | 3713 (55)<br>1.5%   | 4200 (122)<br>2.9%   | 960 (7)<br>0.7%     | <b>21,467<br/>(245) 1.1%</b>  |
| <b>Total</b>     | 6,384<br>(151) 2.4% | 11,737<br>(202) 1.7% | 14,305<br>(249) 1.7% | 9,801<br>(247) 2.5% | 14,830<br>(490) 3.3% | 3,647<br>(119) 3.3% | <b>60,704<br/>(1458) 2.4%</b> |

\* 1996 data from Jan. 1 - March 31 only.

**Table 6. Total SCTs, responders and response rates by region for all cervids and for deer and elk in herds not known to be infected or exposed.**

|                  | <b>All Cervids</b>            | <b>Deer</b>                   | <b>Elk</b>               |
|------------------|-------------------------------|-------------------------------|--------------------------|
| <b>Western</b>   | 14,091 (333)<br>2.4%          | 2215 (77)<br>3.5%             | 11,720 (255)<br>2.2%     |
| <b>Central</b>   | 22,118 (763)<br>3.4%          | 1,6360 (702)<br>4.3%          | 5,447 (60)<br>1.1%       |
| <b>Southeast</b> | 3,015 (117)<br>3.9%           | 1,782 (100)<br>5.6%           | 1,226 (28)<br>2.3%       |
| <b>Northern</b>  | 21,467 (245)<br>1.1%          | 17,335 (176)<br>1.0%          | 3,809 (67)<br>1.9%       |
| <b>Total</b>     | <b>60,691 (1458)<br/>2.4%</b> | <b>37,692 (1055)<br/>2.8%</b> | <b>22,202 (410) 1.8%</b> |

**Table 7. Annual estimates of SCT herd specificity for all cervids and for deer and elk herds.**

|                      | <b>1991</b>     | <b>1992</b>      | <b>1993</b>      | <b>1994</b>      | <b>1995</b>      | <b>1996*</b>   | <b>Total</b>              |
|----------------------|-----------------|------------------|------------------|------------------|------------------|----------------|---------------------------|
| <b>Deer Herds</b>    | 45/52<br>(86%)  | 95/117<br>(81%)  | 118/141<br>(84%) | 103/124<br>(83%) | 91/118<br>(77%)  | 17/24<br>(71%) | <b>469/576<br/>(81%)</b>  |
| <b>Elk Herds</b>     | 48/56<br>(86%)  | 70/85<br>(82%)   | 101/130<br>(78%) | 67/87<br>(77%)   | 106/144<br>(74%) | 36/51<br>(71%) | <b>428/553<br/>(77%)</b>  |
| <b>All** Cervids</b> | 95/111<br>(86%) | 168/205<br>(82%) | 225/277<br>(81%) | 177/219<br>(81%) | 203/268<br>(76%) | 53/75<br>(71%) | <b>921/1155<br/>(80%)</b> |

\* 1996 data from Jan. 1 - March 31 only.

\*\* Also includes herds containing both deer and elk.

**Table 8. Individual CCT specificity for deer, elk and all cervids for all regions of the United States.**

|                     | <b>Deer</b>            | <b>Elk</b>             | <b>All Cervids</b>       |
|---------------------|------------------------|------------------------|--------------------------|
| <b>Western</b>      | 81.0% (132/163)        | 90.8% (257/283)        | 87.2% (389/446)          |
| <b>Central</b>      | 83.3% (219/263)        | 92.2% (59/64)          | 85.0% (278/327)          |
| <b>Southeastern</b> | 86.3% (63/73)          | 78.3% (18/23)          | 84.4% (81/96)            |
| <b>Northern</b>     | 97.1% (200/206)        | 90.8% (69/76)          | 95.4% (269/282)          |
| <b>Total</b>        | <b>87.1% (614/705)</b> | <b>90.4% (403/446)</b> | <b>88.4% (1017/1151)</b> |

**Table 9. Herd CCT sensitivity for the two gold standards for all cervids and the deer and elk strata.**

|                    | <b>Gold 1</b> | <b>Gold 2</b> |
|--------------------|---------------|---------------|
| <b>Deer</b>        | 84.6% (11/13) | 86.7% (13/15) |
| <b>Elk</b>         | 91.7% (11/12) | 64.7% (11/17) |
| <b>All Cervids</b> | 90.5% (19/21) | 78.6% (22/28) |

**Table 10. Frequency of bovine and avian responses for false positive animals.**

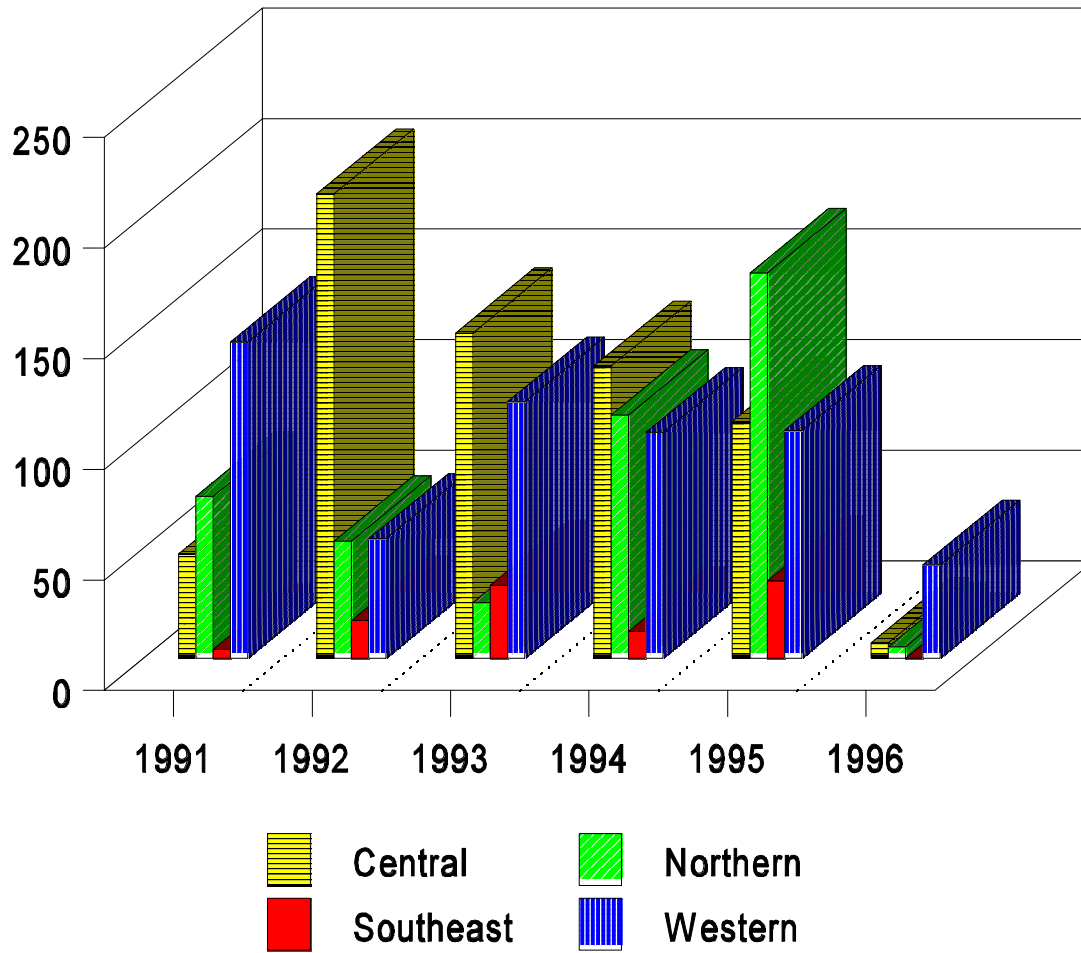
|                    | <b>Avian Response</b> |            |            |            |            |            |            |            |            |              |
|--------------------|-----------------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| <b>Bovine Resp</b> | <b>0.0</b>            | <b>0.5</b> | <b>1.0</b> | <b>1.5</b> | <b>2.0</b> | <b>2.5</b> | <b>3.0</b> | <b>4.0</b> | <b>6.5</b> | <b>Total</b> |
| <b>1.0</b>         | 3                     | 11         | 38         | 0          | 0          | 0          | 0          | 0          | 0          | <b>52</b>    |
| <b>1.5</b>         | 1                     | 1          | 10         | 11         | 0          | 0          | 0          | 0          | 0          | <b>23</b>    |
| <b>2.0</b>         | 5                     | 1          | 4          | 4          | 19         | 0          | 0          | 0          | 0          | <b>33</b>    |
| <b>2.5</b>         | 1                     | 0          | 0          | 1          | 0          | 3          | 0          | 0          | 0          | <b>5</b>     |
| <b>3.0</b>         | 0                     | 0          | 2          | 0          | 1          | 2          | 5          | 0          | 0          | <b>10</b>    |
| <b>4.0</b>         | 0                     | 0          | 0          | 1          | 2          | 0          | 1          | 1          | 0          | <b>5</b>     |
| <b>5.0</b>         | 0                     | 0          | 1          | 0          | 1          | 0          | 0          | 2          | 0          | <b>4</b>     |
| <b>6.0</b>         | 0                     | 0          | 0          | 0          | 1          | 0          | 0          | 0          | 0          | <b>1</b>     |
| <b>7.5</b>         | 0                     | 0          | 0          | 0          | 0          | 0          | 0          | 0          | 1          | <b>1</b>     |
| <b>Total</b>       | <b>10</b>             | <b>13</b>  | <b>55</b>  | <b>17</b>  | <b>24</b>  | <b>5</b>   | <b>6</b>   | <b>3</b>   | <b>1</b>   | <b>134</b>   |

**Table 11. Frequency of bovine and avian responses for false negative animals.**

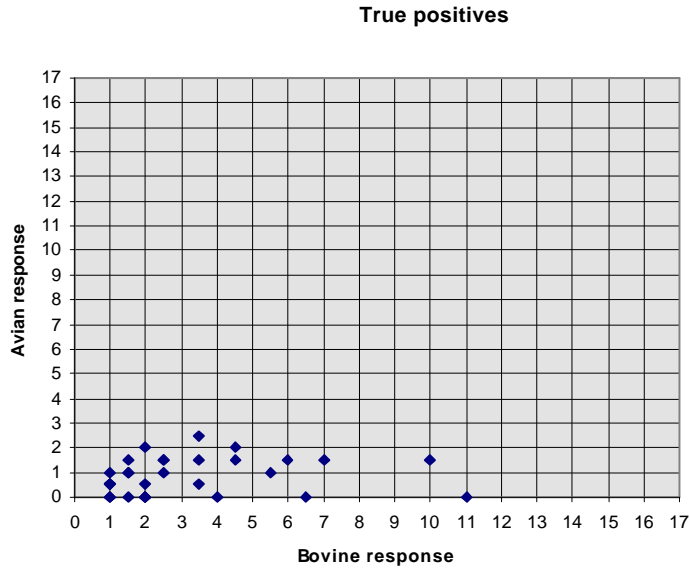
|                        | <b>Avian Response</b> |            |            |            |              |
|------------------------|-----------------------|------------|------------|------------|--------------|
| <b>Bovine Response</b> | <b>0.0</b>            | <b>0.5</b> | <b>1.0</b> | <b>1.5</b> | <b>Total</b> |
| <b>0.0</b>             | 6                     | 1          | 2          | 0          | <b>9</b>     |
| <b>0.5</b>             | 1                     | 2          | 0          | 0          | <b>3</b>     |
| <b>1.0</b>             | 0                     | 0          | 0          | 2          | <b>2</b>     |
| <b>Total</b>           | <b>7</b>              | <b>3</b>   | <b>2</b>   | <b>2</b>   | <b>14</b>    |

**Table 12. Frequency of bovine and avian responses for true positive animals.**

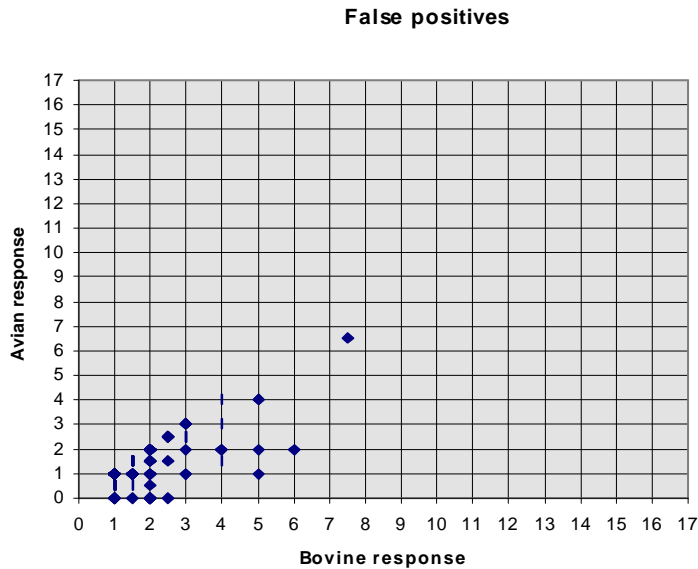
|                        | <b>Avian Response</b> |            |            |            |            |            |              |
|------------------------|-----------------------|------------|------------|------------|------------|------------|--------------|
| <b>Bovine Response</b> | <b>0.0</b>            | <b>0.5</b> | <b>1.0</b> | <b>1.5</b> | <b>2.0</b> | <b>2.5</b> | <b>Total</b> |
| <b>1.0</b>             | 2                     | 3          | 1          | 0          | 0          | 0          | <b>6</b>     |
| <b>1.5</b>             | 1                     | 0          | 2          | 1          | 0          | 0          | <b>4</b>     |
| <b>2.0</b>             | 3                     | 1          | 0          | 0          | 1          | 0          | <b>5</b>     |
| <b>2.5</b>             | 0                     | 0          | 1          | 2          | 0          | 0          | <b>3</b>     |
| <b>3.5</b>             | 0                     | 1          | 0          | 1          | 0          | 1          | <b>3</b>     |
| <b>4.0</b>             | 1                     | 0          | 0          | 0          | 0          | 0          | <b>1</b>     |
| <b>4.5</b>             | 0                     | 0          | 0          | 1          | 1          | 0          | <b>2</b>     |
| <b>5.5</b>             | 0                     | 0          | 1          | 0          | 0          | 0          | <b>1</b>     |
| <b>6.0</b>             | 0                     | 0          | 0          | 1          | 0          | 0          | <b>1</b>     |
| <b>6.5</b>             | 1                     | 0          | 0          | 0          | 0          | 0          | <b>1</b>     |
| <b>7.0</b>             | 0                     | 0          | 0          | 1          | 0          | 0          | <b>1</b>     |
| <b>10.0</b>            | 0                     | 0          | 0          | 1          | 0          | 0          | <b>1</b>     |
| <b>11.0</b>            | 1                     | 0          | 0          | 0          | 0          | 0          | <b>1</b>     |
| <b>Total</b>           | <b>9</b>              | <b>5</b>   | <b>5</b>   | <b>8</b>   | <b>2</b>   | <b>1</b>   | <b>30</b>    |



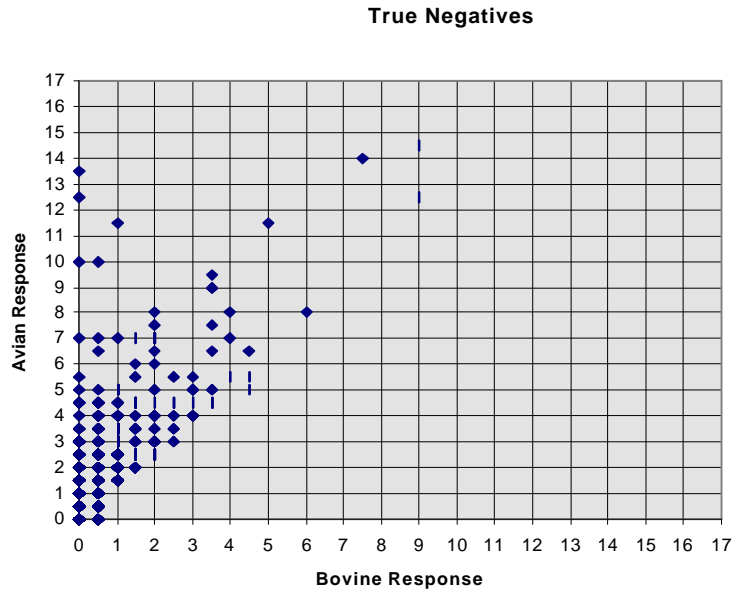
**Figure 1. Number of animals comparative cervical tested each year by region of the United States. N = 1750 (1996 data from Jan. 1 - March 31 only.)**



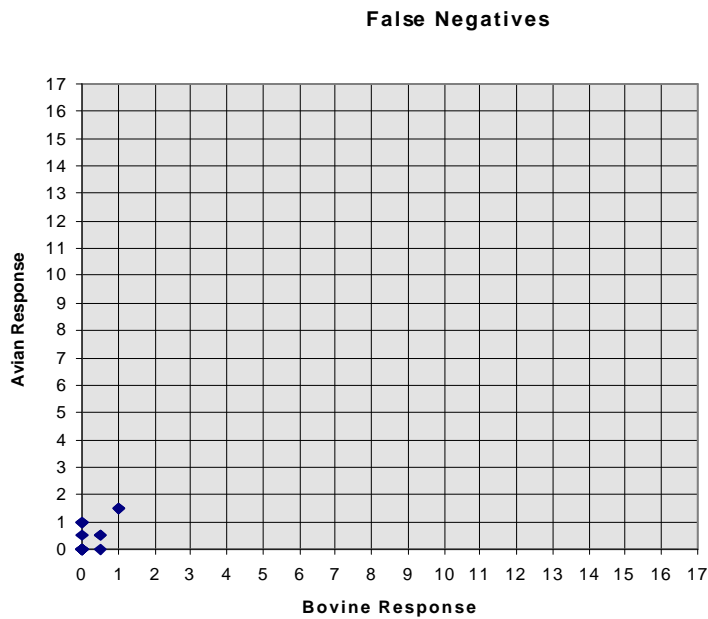
**Figure 2. Scatterplot of the size of reaction to bovine PPD vs. Avian PPD for True Positives. (N=30) See Table 12 for raw data.**



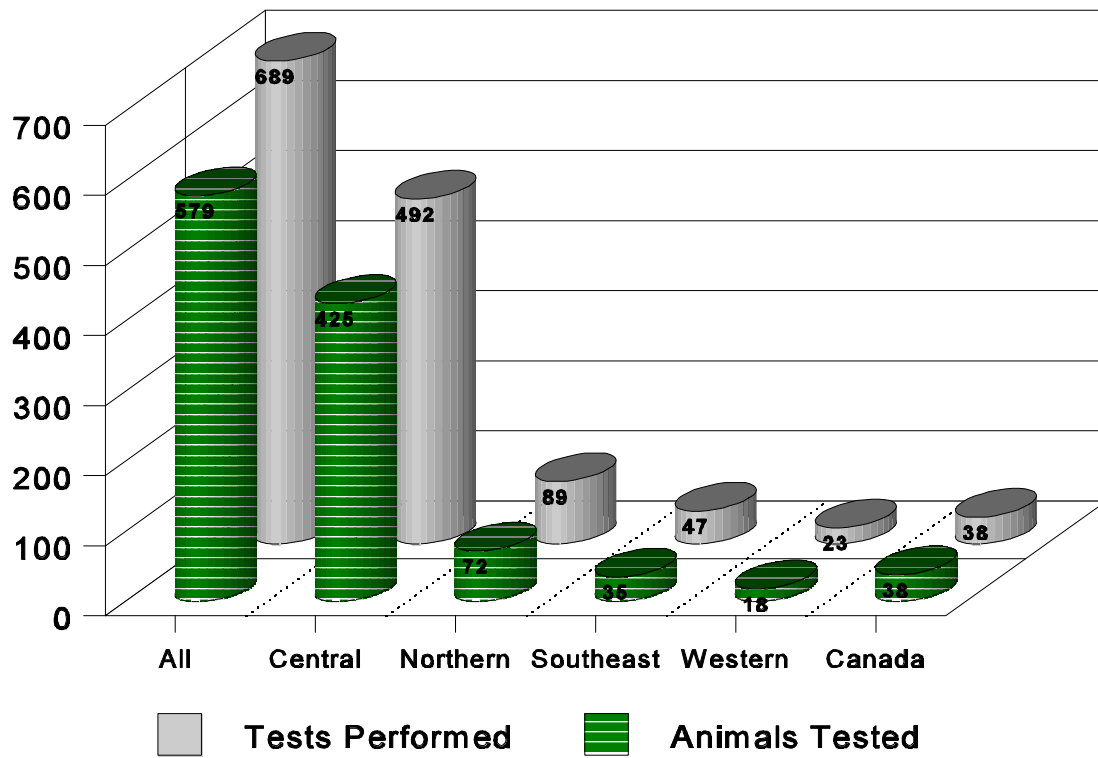
**Figure 3. Scatterplot of the size of reaction to bovine PPD vs. Avian PPD for False Positives. (N=134) See Table 10 for raw data.**



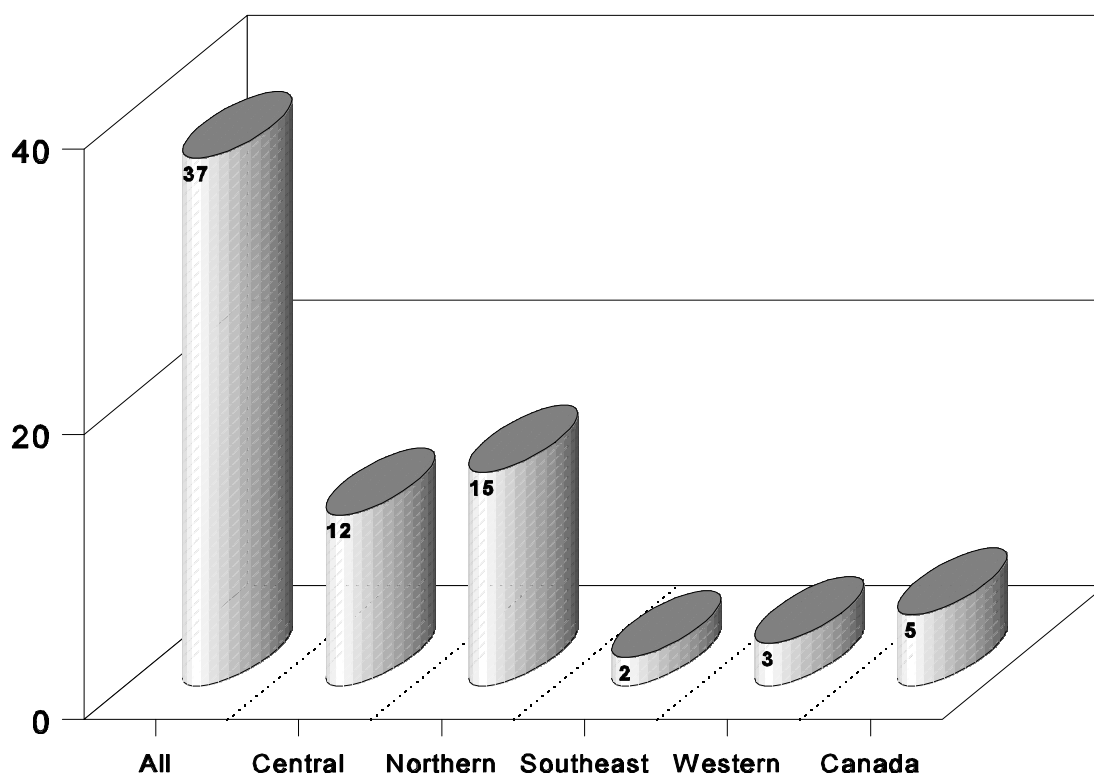
**Figure 4. Scatterplot of the size of reaction to bovine PPD vs. Avian PPD for True Negatives. (N= 1017)**



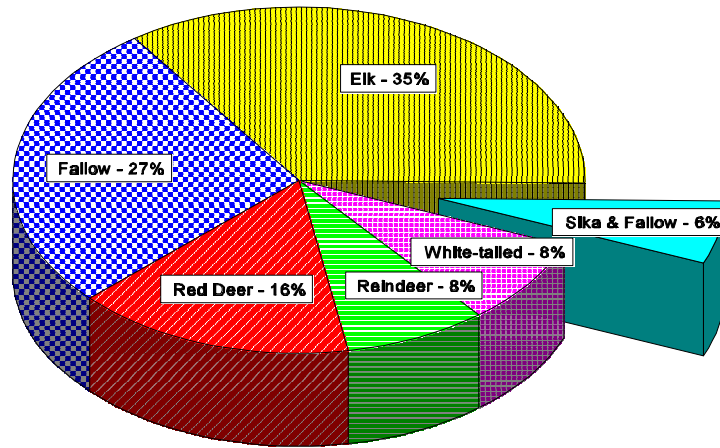
**Figure 5. Scatterplot of the size of reaction to bovine PPD vs. Avian PPD for False Negatives. (N= 14) See Table 11 for raw data.**



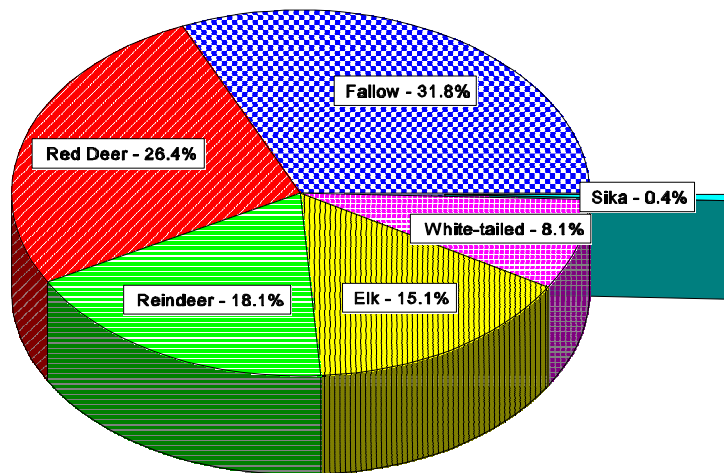
**Figure 6. Number of BTB tests performed and animals tested by region including Canada from May 1994 - June 1996.**



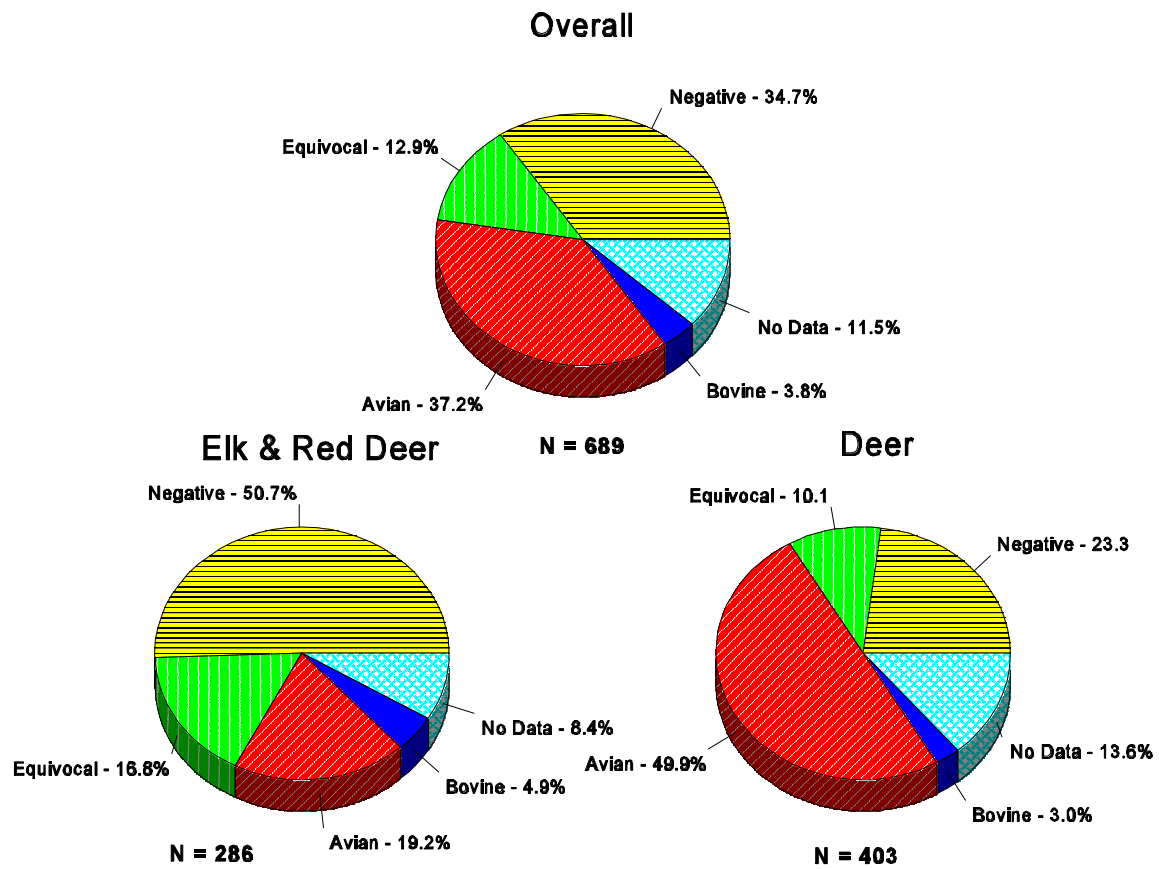
**Figure 7. Number of premises BTB tested by region including Canada from May 1994 - June 1996.**



**Figure 8. Percent species BTB tested (N= 689).**



**Figure 9. Percent of BTB premises raising each species (N=37).**



**Figure 10. BTB test results.**

## Discussion

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Cervids from the Northern region's apparently negative herds were about one third as likely to be classified as positive to the SCT than cervids from the other regions combined. Also, when comparing the apparent false positive responses to the CCT of the Northern region's cervids to the cervids from other regions combined, the Northern region's cervids were nearly one third as likely to have a false positive result. Reasons for the differences in regional SCT response rates and regional CCT false positive responses could be due to: (1) differences in exposure to mycobacteria other than *M. bovis*, (2) differences in the proportion of anergic animals, (3) differences in application and interpretation of the test, (4) differences in the frequency of testing, and (5) differences in the reason for testing. Until regional differences can be explained, the possibility exists that herds being called negative may actually be harboring infection.

Although the difference in SCT response rates of deer compared to elk was small, (1 percent) it was significant at  $p < 0.05$ . This could be due to a biologic difference between the species, as well as the reasons mentioned above.

Because tuberculin test data were not gathered specifically for the purpose of analysis, inadequacies in the data exist. As a result, there were insufficient data for the individual animal sensitivity calculations for the CCT. If one assumes that the 14 test negative animals from which *M. bovis* was isolated were infected at the time of testing, it appears the test was unable to correctly identify these infected animals. Nine of these 14 animals did not have a bovine response at all, and none had a bovine response  $> 1\text{mm}$ . This suggests that the suspect range of the cervid scatterplot cannot be increased to enhance sensitivity without including additional truly non-diseased animals. However, at least three of the 14 test negative animals converted to positive status upon retest, suggesting

that these animals were not permanently anergic. Again, it is possible that these animals were not infected at the time of the test and were truly negative at that time. The evaluation of a larger population of truly diseased animals is needed to determine the distribution of PPD responses and to determine the proportion of false negative animals that convert to positive status upon retest.

Assumptions of the disease status of herds and individual animals were necessary, and may or may not reflect the true situation. *M. bovis* is difficult to isolate, and can be missed on culture. Thus, confidence in a negative culture result is diminished. Exclusion of exposed herds or animals from exposed herds in which *M. bovis* isolation may have been missed was an attempt to increase the confidence that the herds used in specificity calculations were truly negative.

Because individual animal post mortem data for the SCT were unavailable, individual animal sensitivity and specificity could not be determined. In order to collect the necessary data, guidelines should be followed as outlined in "Criteria for evaluating experimental tuberculosis test performance for official test status." When individual sensitivity values are available, a dynamic economic/epidemiologic model can be created. This model could predict the spread of occult disease and its economic impacts.

## References

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